(12) UK Patent Application (19) GB (11) 2 288 022 (13) A

(43) Date of A Publication 04.10.1995

(21) Application No 9405708.0

(22) Date of Filing 23.03.1994

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(51) INT CL[6]
G01N 27/02

(52) UK CL (Edition N)
G1N NCCJ N19B2Q N19B2X N19D1X N19H12 N19X7
U1S S1081

(56) Documents Cited
GB 2210693 A GB 1398735 A GB 1132763 A
WO 87/01455 A1 US 4881025 A

(58) Field of Search
UK CL (Edition M) G1N NCCA NCCE NCCJ NCXA NCXB NCXC NCXX
INT CL[5] G01N 27/00 27/02 27/04 27/12 27/22 33/02 33/04 33/06 33/08 33/10 33/12
Online dabases: WPI

(54) Method of sensing the condition of a piece of food

(57) The method comprises a) applying a current or voltage impulse having three or more Fourier components to a piece of food, b) detecting the resulting transient voltage or current in the piece of food in the time and/or frequency domain, and c) measuring the difference between characteristic features of the transient and those of a reference response in the time and/or frequency domain. The applied impulse may have a square or step waveform. To ensure a good signal to noise ratio over a wide bandwidth, a plurality of square waves of different frequencies may be used (eg. 24.4Hz, 488.3Hz, 9.76KHz and 244KHz). The detected signal may be fast Fourier transformed into the frequency domain and the condition of the food determined from the number of points where the susceptance vs. frequency plot crosses zero (eg. 1 crossing point indicates fresh meat, more than 1 indicates thawed meat). Alternatively, the condition may be determined from the slope of, or the number of maxima in, the graph of conductance vs. frequency. In further alternatives, the difference between the shape of the detected transient response in the time domain and that of a known response may be measured directly, or the response in the frequency domain may be detected directly using frequency-selective filters coupled via respective peak detectors to sample and hold circuits.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

27 +3 95

Fig.1.

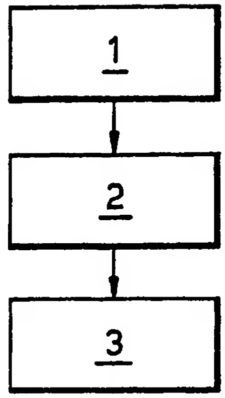


Fig.2.

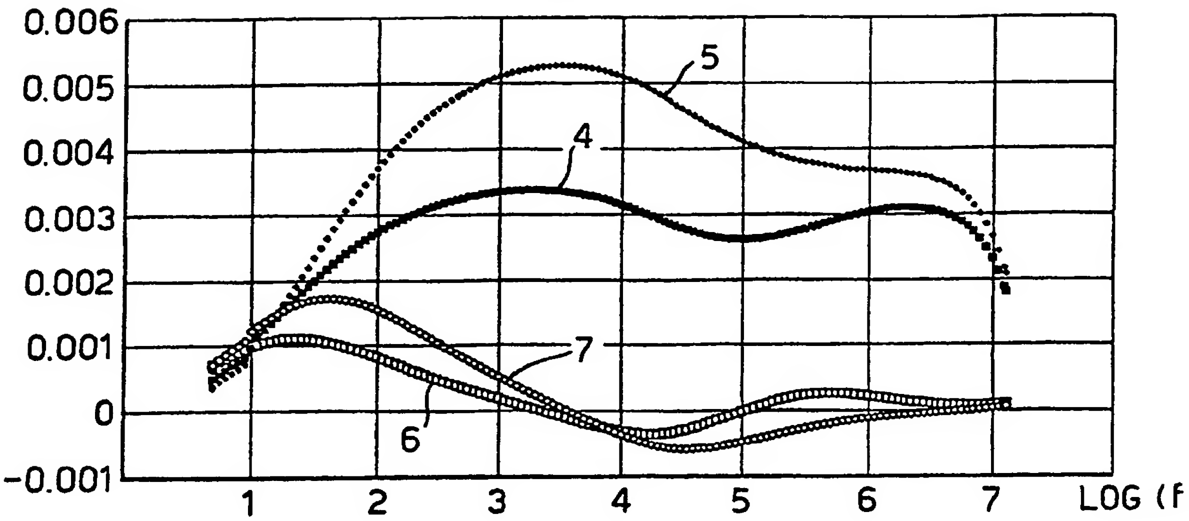


Fig.3.

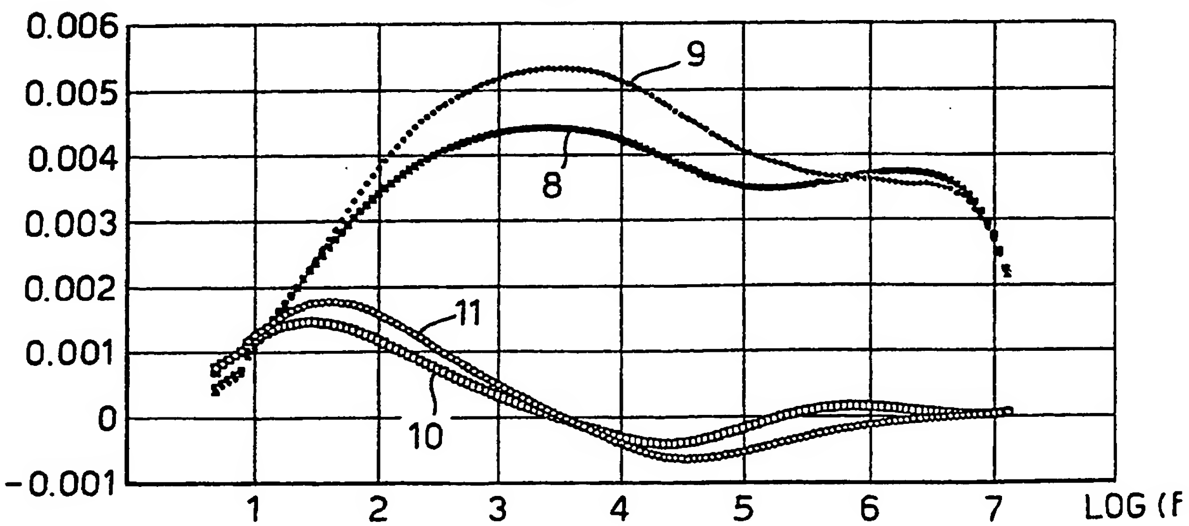


Fig.4.

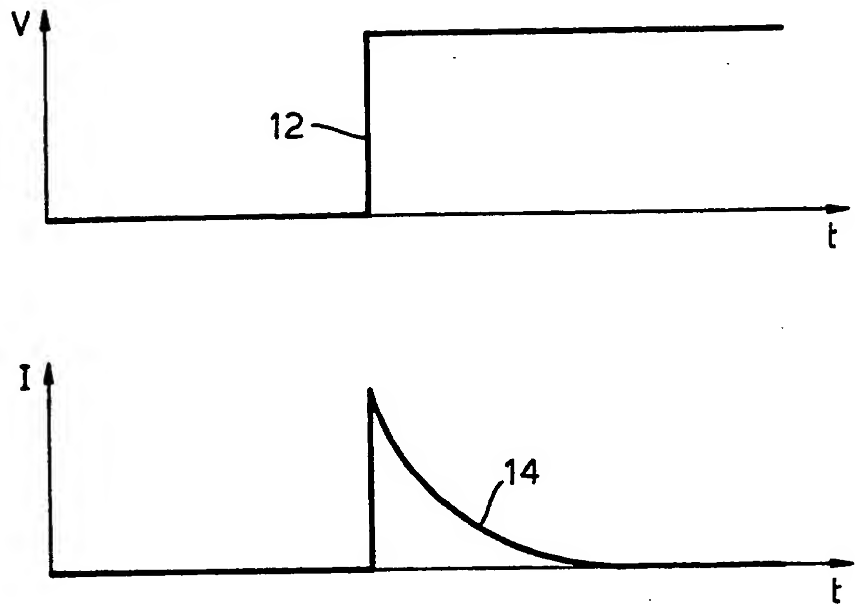
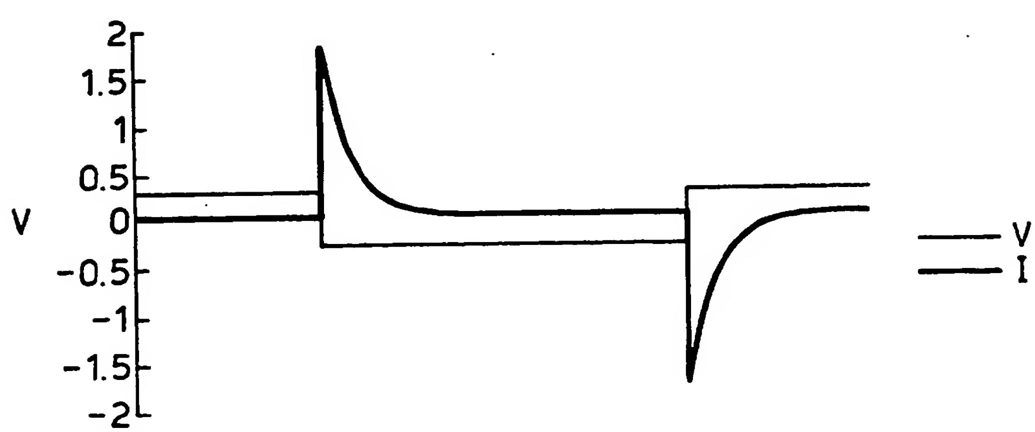


Fig.5.



27 4 3 95

Fig.6.

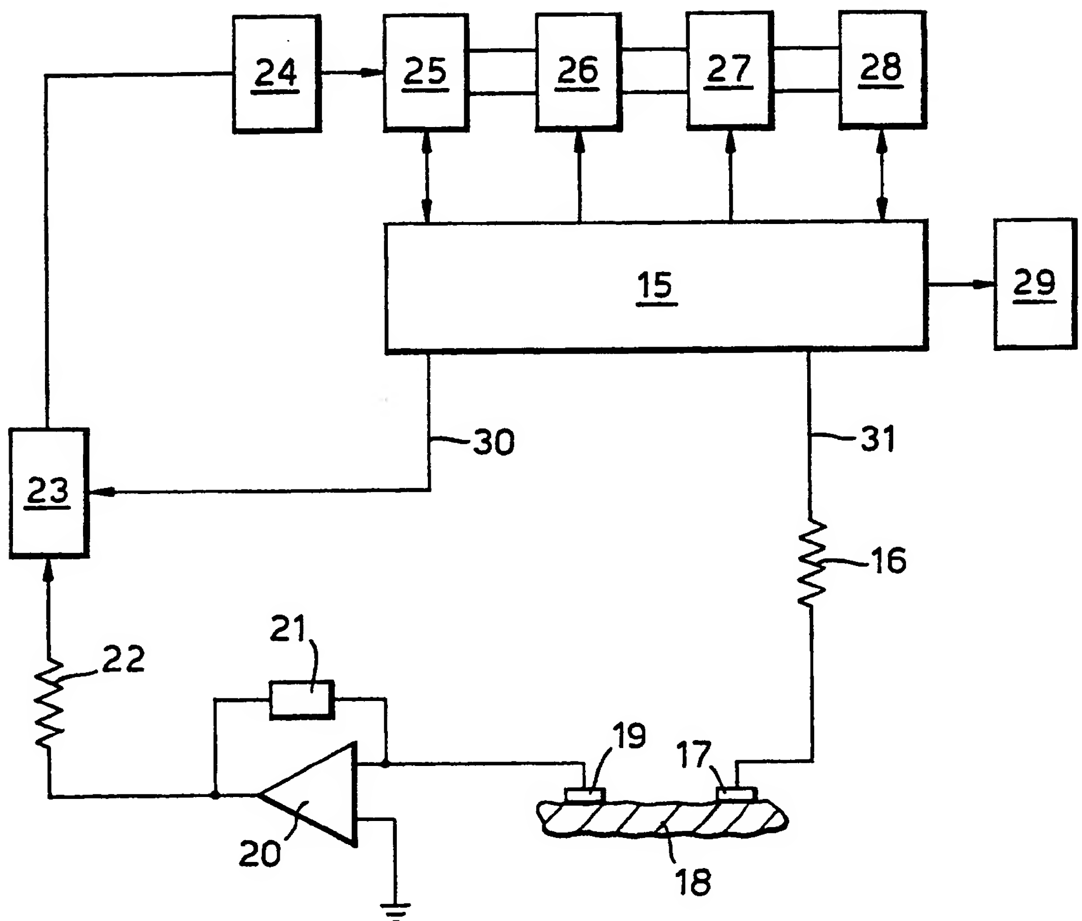


Fig.7.

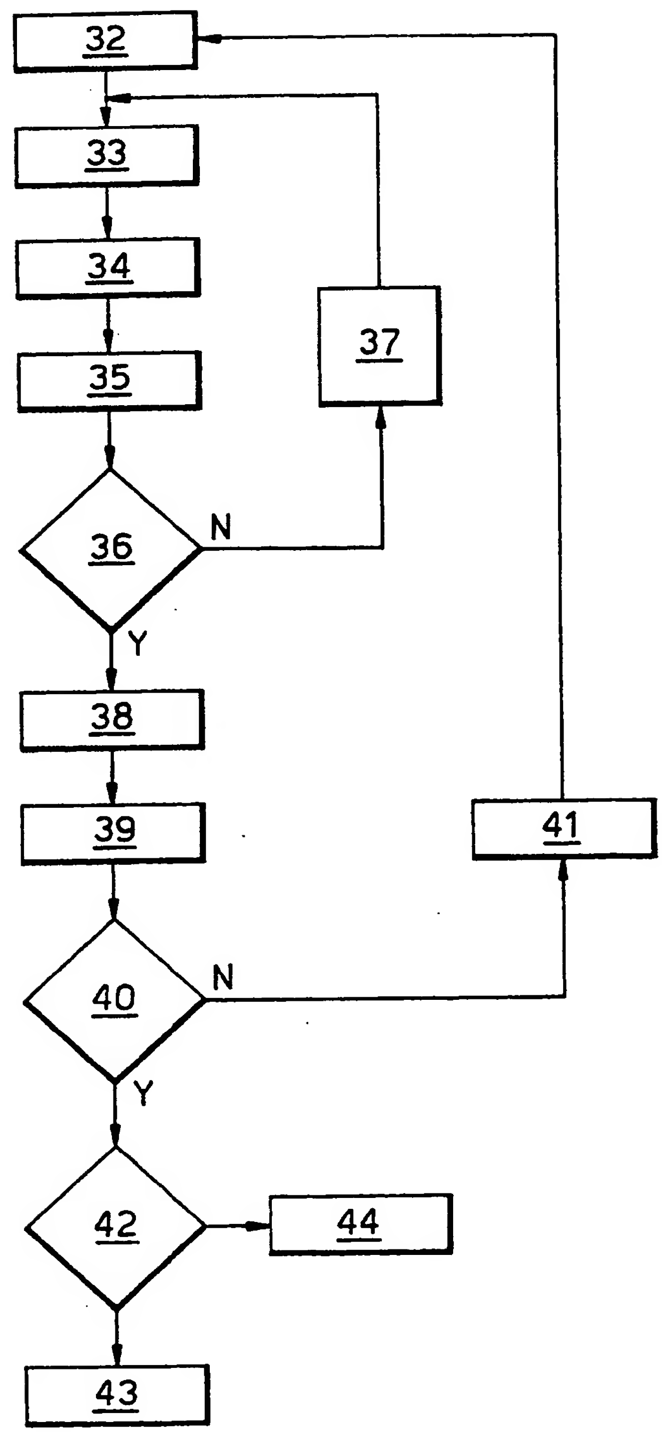
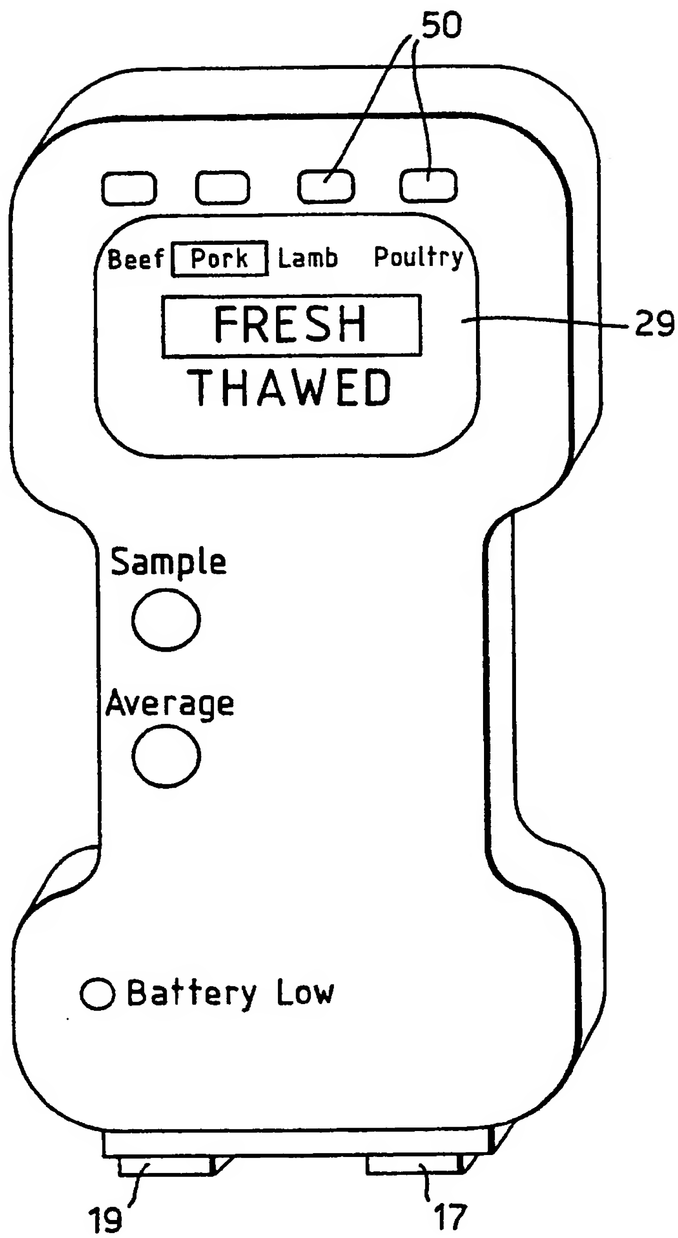


Fig.8.


50
Beef
Pork
Lamb
Poultry
FRESH
THAWED
29
Sample
Average
Battery Low
19
17

METHOD OF SENSING THE CONDITION OF A PIECE OF FOOD

This invention relates to a method of sensing the condition of a piece of food, for example meat. This invention also relates to apparatus for carrying out the above method.

When evaluating the condition of food products, subjective tests such as observing the colour, firmness or smell of the food are often performed. Such methods require good judgement and much experience. For these reasons electrical methods of determining the freshness of food, such as for example fish, have been developed. One method developed in Germany many years ago measures the electrical resistance of a fish at two frequencies and determines its freshness from the ratio of the two readings. Another method and apparatus disclosed in UK Patents GB 1262749 and GB 1287190 measures the power factor of fish tissue at a single frequency to determine its freshness. These methods can suffer from a number of disadvantages. Geometrical effects may dictate that specific points on the fish must be contacted. Readings are often not reproducible, due to skin damage or the presence of subcutaneous fat (amongst other things). Other important condition factors (such as whether the food has previously been frozen and then thawed) are difficult to determine using such methods. The apparatus used to measure the electrical properties of the food is expensive and complex. The apparatus is difficult to use for sensing the condition of different types of food such as chicken or lamb as extensive look-up tables would be required. The apparatus also requires a temperature measuring device as the results obtained are temperature-dependent.

It is an object of the present invention to enable these disadvantages to be mitigated.

According to a first aspect of the invention, there is provided a method of sensing the condition of a piece of food, comprising

a) applying an electrical impulse having three or more Fourier components to a piece of food,

b) detecting the resulting transient voltage or current produced in the piece of food in the time and/or frequency domain,

c) measuring the difference between characteristic features of the detected transient and those of a reference response in the time and/or frequency domain, and indicating into which of a plurality of possible conditions the piece of food falls.

This method can be used to discriminate between, for example, fresh and thawed meat using simple apparatus. The method can also be used for different types of food depending upon the reference response chosen for the comparison.

The method may employ a plurality of applied impulses, in which case a bo: car integrator or phase sensitive detector can be used to improve the signal to noise ratio.

The transients may be averaged prior to measurement of the difference between the characteristic features with those of a reference response. This can give the ability to average transients over different parts of the food, or to average the response of different pieces of food from the same batch to improve the confidence level in statistical analysis.

The impulses may comprise a plurality of sets of periodic waveforms, each set having a different respective period. This can enable a good signal to noise ratio over a very wide frequency bandwidth to be maintained, although the Fourier components of each set of waveforms will have amplitudes which decrease with increasing frequency.

According to a second aspect of the invention, there is provided apparatus comprising an electrical impulse generator, coupling means to couple the impulse to a piece of food, a detector for detecting the resulting transient current or voltage transient in the piece of food, means for detecting whether a detected transient falls into one of a plurality of possible transient types, for enabling a method as described above to be put into effect.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings in which :-

Figure 1 shows a flow diagram of a method according to the invention,

Figures 2 and 3 show the electrical properties of both fresh and thawed chicken breast at 4°C and at 9°C respectively,

Figure 4 shows an applied impulse and the resulting transient response detected,

Figure 5 shows a plurality of periodic impulse waveforms and the transient response detected,

Figure 6 shows a circuit diagram of apparatus according to the invention,

Figure 7 shows a flow diagram of the operation of the circuit of Figure 6, and

Figure 8 shows an external view of the apparatus of Figure 6.

In order to provide an understanding of the invention, the variation of the electrical properties of foods as a function of time and frequency will first be described. For example, when meat is frozen then thawed its cellular structure changes. Cell membranes degenerate making it easier for electrical currents to flow in the meat after thawing. Figure 2 shows experimental data from measurements of the electrical properties of both "fresh" and "frozen then thawed" chicken breast at 4°C. These measurements were taken using an impedance analyzer having electrodes in contact with the meat. The y axis has the units of Siemens, whilst the x axis has the units of the logarithm to the base 10 of the frequency of the measurement in Hertz. Curves 4 and 5 denote the real part of the impedance, also known as the conductance (G), for "fresh" and "frozen then thawed" meat respectively. Curves 6 and 7 denote the imaginary part of the impedance, also known as the susceptance (B), for "fresh" and "frozen then thawed" meat respectively. Figure 3 shows experimental data from measurements of the electrical properties of both "fresh" and "frozen then thawed" chicken breast at 9°C. The x and y axes have the same units as in Figure 2. Curves 8 and 9 denote the conductance (G), for "fresh" and "frozen then thawed" meat respectively. Curves 10 and 11 denote the susceptibility (B), for "fresh" and "frozen then thawed" meat respectively. It can be seen from these results that the frequency dependence of G and B are different in the two cases at both temperatures, and that this difference is more pronounced at frequencies below 100 kiloHertz. Although the magnitude of the differences depend upon the electrode type and geometry, temperature and meat species, fresh meat provides a characteristic "fingerprint" which is significantly different from that of frozen then thawed meat. This difference may be used in a method of sensing the condition a piece of meat with an unknown thermal history is in. As the shape of the curve also changes with conditions such as age of the meat post mortem, tenderness, fat or water content, a similar method may be used to determine other condition factors.

Figure 1 shows a flow diagram of a method of sensing the condition of pieces of food according to the invention. In this diagram, box 1 denotes the step of applying a current or voltage impulse having three or more harmonic frequency components to a piece of food, box 2 denotes the step of detecting the resulting voltage or current transient response in the piece of food in the time and/or frequency domain, and box 3 denotes measuring the difference between the detected response and a known response in the time and/or frequency domain, and indicating the result of the measurement. A minimum of three frequency components are required to enable the presence of : maximum or minimum or point of inflexion or zero crossing points to be determined from measurements of the electrical properties versus frequency. Three components would also be required to determine the slope of a graph at a given point with accuracy. In practice the more frequency components present in the impulse the better. For this reason square wave or step impulses are to be preferred.

One of many possible implementations of the method of Figure 1 uses an impulse 12 as shown in Figure 4, in the form of a voltage step which is applied to a piece of food (i.e. step 1 of Figure 1). Being a step function, this impulse may be represented as a Fourier integral over a wide frequency band in the frequency domain. Figure 4 also shows the resulting transient current response 14 which is detected in the meat in the time domain (i.e. step 2 of Figure 1). In this embodiment of the method the detected transient current response is then fast Fourier transformed into the frequency domain. An automated correlation is used to detect the number of points where the graph of B versus frequency crosses zero between 500 Hz and 200 kHz. If the number of crossing points is 1, then the meat is in the condition "fresh", if the number of crossing points exceeds 1, then the meat is in the condition "thawed".

Clearly there are many criteria which may be used to test which condition a piece of food is in for the step in which differences are measured (step 3 of Figure 1). For example, the number of maxima in the graph of G versus frequency may be used:- two maxima for "fresh", one maximum for "thawed". As a further example, the slope of the graph of G versus frequency at approximately 200 kHz may be used, greater than zero indicating "fresh" and less than zero indicating "thawed".

In all of the above examples, the current transient is detected in the time domain then Fourier transformed into the frequency domain. As an alternative, one may

directly measure the difference between the shape of a detected transient response in the time domain and the shape of a known response in the time domain. As a further alternative, the transient response may be detected directly in the frequency domain, using for example a plurality of frequency selective filters, each coupled via a respective peak detector to a respective sample and hold circuit. In this case the response may be measured and compared directly to a known response in the frequency domain without the requirement for Fourier transformation.

Although all the above embodiments use a step-function voltage change as the applied impulse, any impulse may be employed which is rich in harmonic components when analyzed in the frequency domain. Thus a pulse containing three or more frequency components may be used as an alternative.

Detection of the transient in the food may be made easier by using techniques which will increase the effective signal to noise ratio. One such technique is to use a pulse train as shown in Figure 5. The transient may then be extracted from background noise using a phase sensitive detector, box-car integrator circuit or similar techniques. Even simple averaging of the responses to a series of pulses will reduce the effect of noise and make the shape of the averaged response more reproducible and smoother.

A method using multiple pulses is used in the apparatus shown in Figure 6. In Figure 6 the apparatus for sensing the condition of a piece of food comprises a voltage impulse generator (15, 16), means consisting of two food-engaging electrodes (17, 19) to apply the generated impulse to a piece of food (18), a detector (20) for detecting the transient current response of the food, storage means (28) for storing a known response, means (27) to measure the difference between the known response and the detected response, and indicator means (29) for indicating the result of this measurement. In one of many possible implementations of this circuit, a Philips microcontroller type 87C552 is used to provide the controller 15, sample and hold circuit 24, analogue to digital converter 25, pre-processing result memory 26, post processor 27, and post processor result memory 28. Unfortunately the sample and hold circuit 24 does not have a hold time sufficiently accurately controlled for this application, therefore an additional sample and hold circuit 23 is used in series. Circuit 23 is an Analog Devices AD 585AQ unit which is controlled by an output 30 from the controller 15. The voltage impulses are provided by an output 31 from the controller 15, which is fed through a

2k ohm resistor 16 to minimize the effects of impedance changes in the meat 18 on the impulse. The detector 20 comprises a Burr Brown OPA621 operational amplifier (in a negative feedback configuration) having a bandwidth of 500 MHz, powered from a +/- 5 volt power supply (not shown). A 680 ohm resistor 21 is provided in parallel with the detector 20.

The microcontroller 15 in Figure 6 is programmed to perform the operations shown in the flow diagram of Figure 7. In this Figure the boxes have the following significances:-

(32) - cause controller 15 of Figure 6 to output a square wave periodic signal of a given period at output 31 of Figure 6

(33) - cause controller 15 of Figure 6 to output a signal via output 30 to sample and hold circuit 23 to take sample

(34) - convert signal to digital form using ADC 25

(35) - store the result in memory 26

(36) - decide if results for the square wave of the given period are complete,
- if not, go back to step (33) via step (37) in which a given time delay is introduced between the application of a step function in step (32) and step (33)
- if so, continue

(38) - processor 27 performs Fourier transform on results stored in memory 26

(39) - store the transformed results into another memory (28 in Figure 6)

(40) - decide if results for all periods are complete,
- if not, go back to step (32) via step (41) in which the period of the square wave signal is changed to a further period for which no results have yet been taken
- if so, continue

(42) - perform comparison of results from memory 28 with a known response using processor 28, and indicate result via indicator 29 if the response is similar (43) or if the response is not similar (44).

Voltage impulses forming a square wave pulse train as in the above example may be used to measure the response up to frequencies of the order of 1 MHz, provided

that the rise time at the voltage transition is sufficiently fast. When a square wave with a low fundamental frequency is Fourier transformed, its Fourier components decrease in amplitude with increasing frequency. Therefore in order to ensure a good signal to noise ratio over a wide bandwidth up to 1 MHz, a total of four square wave frequencies are used in the apparatus described with reference to Figures 6 and 7; namely, 24.4, 488.3, 9,760, and 244,000 Hz.

Sampling using only one or two square wave frequencies will be adequate for many purposes. Fitting data to, for example, a polynomial expansion, will give coefficients which may be characteristic of fresh or frozen then thawed meat as the case may be. Other methods of determining whether two measured responses are of food of the same condition may be employed, for example locating the presence and number of stationary points on the G versus frequency characteristic, or detecting the gradient of the curve in a specified frequency range etc. as mentioned earlier.

The exterior of a simple hand held portable version of the apparatus of Figure 6 is shown in Figure 8. In this case the indicator means 29 is a liquid crystal display, although coloured lights or a sound alarm may be used alternatively or in addition. The LCD screen may be used in addition to display confidence levels of the decision or temperature of the meat. The food-engaging electrodes 17 and 19 in this case are in the form of studs. Differently shaped electrodes may be used, for example pins which may pierce surface skin and fat layers of meat to give a reading more representative of the underlying meat. The apparatus shown in this figure has several buttons 50 to preselect which type of food is to be tested. Such buttons are optional, as a simpler form of the apparatus may be dedicated for application to a particular type of food.

Although in the above examples two food-engaging electrodes have been employed, conventional 4 point probe techniques may be used to minimise the effects of contact polarization. This phenomenon can exaggerate the measured conductivity at low frequencies which might in some cases mask a characteristic feature important for comparison purposes.

As an alternative to apparatus which uses voltage pulses, capacitive coupling and food-engaging electrodes, current impulses with inductive coupling to the meat via coils may be used. In such apparatus it is not necessary to have food-engaging electrodes. Such an arrangement gives the advantage of not requiring good contact between the

apparatus and the food to be sensed, so that food protected by cellophane or plastic wrapping may be tested without removing the wrapping.

Although the above method and apparatus has been designed to be used without a temperature sensing element, such a sensor may be incorporated if desired.

CLAIMS

1. A method of sensing the condition of a piece of food, comprising
   a) applying an electrical impulse having three or more Fourier components to a piece of food,
   b) detecting the resulting transient voltage or current produced in the piece of food in the time and/or frequency domain,
   c) measuring the difference between characteristic features of the detected transient and those of a reference response in the time and/or frequency domain, and indicating into which of a plurality of possible conditions the piece of food falls.
2. A method as claimed in claim 1 in which the detected response in the time domain is Fourier transformed into the frequency domain prior to comparison of its characteristic features to those of a reference response in the frequency domain.
3. A method as claimed in claim 1 in which a plurality of electrical impulses are applied.
4. A method as claimed in claim 1 in which the detected transients are averaged prior to the comparison of its characteristic features to those of a reference response.
5. A method as claimed in claim 3 in which the impulses comprise a plurality of sets of periodic waveforms, each set having a different respective period.
6. A method as claimed in any preceding claim in which the reference response is chosen from a plurality of possible responses associated with respective food types or conditions.
7. A method as claimed in any preceding claim in which the condition being sensed is whether the food has been frozen then thawed or is fresh.
8. A method substantially as herein described with reference to Figure 1 and Figure 4 or Figure 5 or Figure 7 of the accompanying diagrammatic drawings.
9. Apparatus comprising an electrical impulse generator, coupling means to couple the impulse to a piece of food, a detector for detecting the resulting transient current or voltage transient in the piece of food, means for detecting whether a

detected transient falls into one of a plurality of possible transient types, for enabling a method as claimed in any preceding claim to be put into effect.

10. Apparatus as claimed in claim 9 in which the coupling means comprises a plurality of food-engaging electrodes.

11. Apparatus substantially as herein described with reference to Figure 8 or Figure 6 of the accompanying diagrammatic drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number GB 9405708.0	

Relevant Technical Fields

(i) UK Cl (Ed.M) G1N NCCA, NCCE, NCCJ, NCXA, NCXB, NCXC, NCXX)

(ii) Int Cl (Ed.5) G01N 27/00, 27/02, 27/04, 27/12, 27/22, 33/02, 33/04, 33/06, 33/08, 33/10, 33/12

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASE: WPI

Search Examiner
M J BILLING

Date of completion of Search
13 JUNE 1994

Documents considered relevant following a search in respect of Claims :-
1-10

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2210693 A	(SCANFLOW) See eg. Figure 1; Abstract, page 11 lines 1 - page 13 line 5	1, 3, 9 at least
X	GB 1398735	(EMME) eg. See page 2 lines 18-47, page 10 lines 18-21	1, 3, 9 at least
X	GB 1132763	(ROWNTREE) eg. See page 2 lines 17-29, page 3 lines 61-84	1, 3, 9 at least
X	WO 87/01455 A1	(FULLER) eg. See Abstract, page 1 lines 13-22, page 3 line 35 - page 4 line 29	1, 3, 9 at least
X	US 4881025	(DIOTEC TRUST) eg. See Figure 7; Abstract, column 10 line 35 - column 11 line 13	1, 2, 3, 6, 9 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).